Geographic Information Systems Based Quantity Takeoffs in Buildings Construction

V. K. Bansal[1] and Mahesh Pal[2]
[1]Department of Civil Engineering, National Institute of Technology Hamirpur, H.P., India
E. Mail: vijaybansal18@yahoo.com
[2]Department of Civil Engineering, National Institute of Technology Kurukshetra, Haryana, India
E. Mail: mpce_pal@yahoo.co.uk

***Abstract*— Paper presents a Geographic Information System (GIS) based quantity takeoffs methodology, which is helpful in increasing the productivity of quantity estimator by reducing the manual work in quantity takeoffs. Proposed methodology also reduces the missing or duplication of various items of work by visualizing each components corresponding to the items in space. Several scripts developed within ArcView3.2 were used to extract the necessary dimensions from the drawings and to perform various calculations for quantity takeoffs. Accurate Bill of Quantities (BOQ) may be generated on the basis of dimensions of various data themes in GIS.**

***Index Terms*— GIS, Quantity takeoffs, Bill of quantity**

I. Introduction

The manual approaches for quantity surveying are becoming outdated, within last three decades automated techniques have changed the way estimates are being produced and will continue to change as new software are being developed. The automation of cost estimation facilitates in decision-making and creative thinking by allowing the designers to quickly recall and review issues relevant to the task at hand [1]. Electronic digitizer, which traces drawings and produces a picture of the item being measured, may be used for automated quantity takeoffs process. Quantity takeoff is a part of the cost estimating process in the construction industry, estimators use construction blueprints, either manually or electronically to estimate the quantities of various types of construction work. The Computer Aided Drafting (CAD) systems are also capable of generating quantity takeoffs [1-2]. Electronic spreadsheets are used for the preparation of pricing sheets. Spreadsheets may quickly perform all mathematical steps for which a quantity estimator spends hours in preparation and checking the calculations. Some of the commercially available estimating software can take the quantities determined either manually, from a CAD file, or with the assistance of digitizer and apply a database of unit prices to calculate the total cost.

GIS has proliferated within civil engineering in the recent years. It is being used to handle various construction project requirements including cost estimate, site layout, route planning, integrating information, construction visualization, and scheduling [3-4]. Cheng and Yang [2] explored the capabilities of GIS in combination with other software for cost estimation. They developed a GIS based tool called MaterialPlan, to assist planners in quantity takeoffs and assessing materials layout design. MaterialPlan uses GIS in combination with CAD systems to compute quantity takeoff based on the dimensions of the drawings as well as to generate Bill of Material (BOM) by using Map/Info and Microsoft Access. BOM is a list that specifies the materials used to build a structure. When a construction company produces a structure, it must keep track of the materials and components used in its creation. The user communicates with the components of system through a custom interface developed using VBA (visual basic application) and MapBasic. The Open Database Connectivity (ODBC) was also used to write/ read the information to/from the associated database.

Recently, Bansal and Pal [5] suggested the use of GIS for cost estimation in a more generalized way by adding new scripts into GIS environment for various cost estimation operations, which allows user to communicate through an interface developed within GIS environment. ArcView3.2, which utilizes the dynamic linkage between the spatial and attribute data, was used for this purpose, therefore, requiring no ODBC. ArcView3.2 has the capability to handle database, thus, avoiding the use of Microsoft Access as suggested in earlier study [2].

Studies carried out by Cheng and Yang [2] and Bansal and Pal [5] used AutoCAD to prepare different data themes, which are the spatial data representation of architectural drawing in GIS. In the earlier studies [2, 5] if designer needs to see the effect of change in the size of rooms in the building on bill of quantities, the drawings need to be edited in AutoCAD. The methodology proposed in this study utilises the ArcGIS 9 to generate the spatial data in place of AutoCAD due to its improved editing capabilities in comparison to ArcView3.2. Although the methodology suggested can utilize the themes generated in AutoCAD but this paper replaces the CAD systems from a GIS based quantity takeoffs procedure. Therefore, paper encourages designer to see the effects of drawing alterations on BOQ.

ArcGIS 9 and ArcView 3.2 are developed by Environmental Systems Research Institute (ESRI) run on standard desktop computer are used in the present work. They are used to create, import, edit, query, map and analyze geographic information. ArcGIS 9 consists of: ArcReader, ArcView, ArcEditor and ArcInfo. ArcReader allows viewing, exploring and printing of spatial information. Like ArcGIS 9, ArcView 3.2 developed by ESRI is also used in this work to perform various tasks. ArcView 3.2 also runs on standard desktop computers in windows environment. ArcView3.2 is a collection of different documents that provide different menu/

DOI:1.IJTUD.01.01.40

command structure to perform various operations. Each document type has its own set of menus, buttons and tools. The CAD systems are also capable of generating material requirement and quantity takeoffs [2]. However, the estimates prepared without detailed engineering data of an organization itself are found to be less accurate [6]. To increase the accuracy of estimates one needs a well-defined engineering data related to the organization itself. Estimates produced from organizational data usually gives better estimate than any published data as it includes group of tasks into consideration such as downtime, cleanup times, lunch, and tea breaks which vary from industry to industry. Therefore, the proposed quantity takeoffs approach explores the database management capabilities of GIS to store, access and manipulate the data that can later be used for correct building cost estimation [7].

II. Research Objective

The main objective behind this study was to develop an easy-to-use GIS based approach for quantity takeoffs in building construction. Other sub-objectives that were to be achieved include accurate BOQ and development of construction resource database within GIS. Several scripts written in Avenue (programming language in ArcView3.2) were added to ArcView3.2 so as to achieve objective of this study. Several in-built GIS functions were also used to perform different operations. Because of the limited editing capabilities of ArcView3.2, ArcGIS 9 was used to generate various data themes representing the complete architectural drawing.

III. Generation of Spatial Data in GIS

This study use vector data model in which simple geometric objects point, line, and polygon are used to represent the geographic spatial features. In spatial geographic database, feature classes are logically organized as themes, where each theme is allowed to have only one type of graphical element (point, line, or polygon). The ArcGIS 9 has CAD like tool/commands to generate the 2D or 3D models. In addition ArcGIS 9 also contains the tools to handle the editing session [8,9]. ArcGIS 9 retains the locations, sizes, and colors/textures of the objects drawn, by maintaining them in a database for subsequent retrieval, analysis and manipulation. The in-built functionality such as delete, move, cut, and paste can also be applied to one or more selected features. Each point, line or polygon theme in spatial database is stored as shapefiles, where a shapefile is the non-topological format for storing the geometric location and attribute information of geographic features in ArcView3.2 or ArcGIS 9 [9,10]. For reshaping the lines and polygons, the vertex edit tool can be used. This tool allows the user to select a vertex and drag it to new locations or delete it. The Split tool may be used to subdivide the polygon into two or more polygons. ArcGIS 9 also allows creating new polygons representing the intersection of different polygons, creating polygon with a hole inside and removing the area of the overlap between the polygons. The Merge tool of ArcGIS, groups the features of a theme into one feature. It combines different features by removing boundaries or nodes between adjacent polygons or lines. Merge also joins non-adjacent features to create one feature (multipart polygon) [9].

Various data themes representing the architectural drawing and possess accurate physical dimensions are used as spatial data in GIS for quantity takeoffs. A single-room hexagonal building shown in Fig. 1 is used to explain the proposed methodology. The various items of the work required to be calculated includes: excavation in foundation; lime concrete in foundation; brick work in foundation; damp proofing course; brick work in superstructure; reinforced cement concrete work; lime concrete in terracing; flooring and plastering work. Each theme corresponds to one or a part of an item whose quantity needs to be estimated. Different features in a theme are merged so as to reduce the number of rows in the attribute table to one. All data themes are stored as the shapefile and their height as attribute. The main attributes required for quantity takeoffs are length, perimeter, and area of various features. Thus, different data themes are created using geographic element either as lines or polygons. The number of themes created for each item of work depends on the shape, openings and thickness at different levels of height etc.

The type of geographic element used to construct the theme will depend on the unit of measurement of the various items of work. For the items of work having units “running meter” and “square meter”, geographic feature line is used to create the data theme. Items having units “cubic meter” and “square meter”, polygon is used to create the data theme. For “square meter” both line and polygon may be used. For details about the spatial editing readers are referred to the earlier study made by Bansal and Pal [4].

IV. Quantity Takeoffs Methodology

The different steps involved in quantity takeoffs are shown in Fig. 1, for quantity takeoffs, an architectural drawing is divided into different data themes. The data themes generated in ArcGIS form the basis of quantity takeoffs. The parameters required for quantity takeoffs of hexagonal building are area and length. Therefore, all features of data themes are created as polygon or line. Different polygons in each theme may be dissolved to form a single or multipart single polygon. Fig. 1 shows all data theme before and after merging different features, where each data theme contains single record, as all features in a theme are merged to one polygon or a line. After merging, all data themes are transferred to ArcView from ArcGIS. In all feature tables of different data themes, the shape is the default field to store shape added information of features. Fields key, items and height are to the feature table of each data theme by using a script written for this purpose. The values in these fields are then entered manually. Key is the common field in all the feature table and the values in this field are entered in a way that it should correspond to one row of the resource table that carry the resource information [7]. The description of the item of work contained by data

DOI:1.IJTUD.01.01.40

theme is entered in field items. For the items measured in "square meter" and "cubic meter" represented by geographic element line and polygon respectively, the values of height

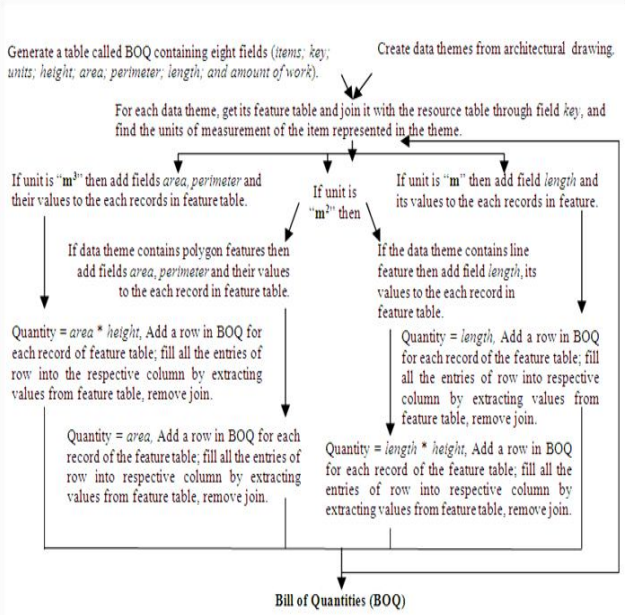

Figure 1. Flow diagram to generate Bill of Quantities in ArcView.

need to be entered in the field height. The entries in the field height will be zero if items of the work are measured in "running meter" and "square meter" represented by line and polygon respectively.

In ArcView, all data themes act as input to generate BOQ. The script used to generate the BOQ creates a new table with eight fields named as description; key; units; height; area; perimeter; length and amount of work. Each record in BOQ corresponds to a particular theme used to represent one or a part of the item of the work.

The paper presents a methodology that uses ArcGIS 9, which provides varieties of interoperability modes including file conversion, entity translation, and direct read/write mode. ArcGIS 9 has the ability to read a variety of CAD data formats without conversion, including DWG, DXF, and DNG. It can also export selected GIS features (points, lines, polygons, and annotation) directly to CAD. ArcGIS 9 also includes an improved bi-directional CAD-GIS translator that can move the data from CAD system to GIS and vice versa which facilitate data sharing.

Conclusions

The study demonstrates the significance of GIS based system for storing and utilizing information related to construction resources to support planning process and quantity takeoffs. The information required for the development of proposed methodology are represented and integrated within a single GIS environment in digital form that can easily be updated. Data themes generated for quantity takeoffs can also be used for the development of the 3D visualization. Therefore, it can be concluded from this work that GIS based approach can be an alternative to the traditional method for cost estimation as well as to handle various project requirements of construction industries. The quantities takeoffs based upon the suggested approach are precise depending upon the dimensions in the data themes.

References

[1] M.A.E. Saleh, "Automation of quantity surveying in construction projects," *Journal of Architectural Engineering*, Vol. 5, No. 4, 1999, pp. 141-148.

[2] M.Y. Cheng, C.Y. Yang, "GIS-Based cost estimate integrated with material layout planning," *Journal Construction Engineering and Management*, Vol. 127, No. 4, 2001, pp. 291-299.

[3] V.K. Bansal, "Potential of GIS to find solutions to space related problems in construction industry," *Proc. World Academy of Science, Engineering and Technology*, Bangkok, Vol. 26, 14-16 December 2007, pp. 307-310.

[4] V.K. Bansal and M. Pal, "Generating, evaluating, and visualizing construction schedule with Geographic Information Systems," *Journal of Computing in Civil Engineering*, Vol. 22, No. 4, 2008, pp. 233-242.

[5] V.K. Bansal, and M. Pal, "Potential of Geographic Information Systems in building cost estimation and visualisation," *Automation in Construction*, Vol. 16, No. 3, 2007, pp. 311-322.

[6] H. Kerzner, *Project Management a Systems Approach to Planning, Scheduling and Controlling*, John Wiley & Sons, New Jersey, 2003.

[7] V.K. Bansal and M. Pal, "*GIS based projects information system for construction management*," Asian Journal of Civil Engineering, Vol. 7, No. 2, 2006, pp. 115-124.

[8] K.T. Chang, *Introduction to Geographic Information Systems*, Tata McGraw-Hill, New Delhi, 2002.

[9] ArcGIS 9, *Introduction to ArcGIS 9 Part I & II*, Environment System and Research Institute. New York Street, Redlands C.A. 2004.

[10] ArcView GIS 3.2, *Reference Manual for Window by ESRI*, Environment Systems and Research Institute, New York Street, Redlands C.A., 1996.

[11] H. Li, C.W Kong, Y.C. Pang, W.Z. Shi, and L. Yu, "Internet-based geographic information systems system for E-commerce application in construction material procurement," *Journal Construction Engineering and Management*, Vol. 129. No. 6, 2003, pp. 689-697

DOI:1.IJTUD.01.01.40